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May 28, 2015

Sent via email and hand delivery

Dan Hall
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RE: *Green River Resources, Inc., Bruin Point Mine, Ground Water Discharge Permit and Related Construction Permit # UGW0700003*

Mr. Hall:

Thank you for the opportunity to comment on the Draft Ground Water Discharge Permit and the related Construction Permit for the Bruin Point Mine. These comments are submitted on behalf of Living Rivers, Utah Physicians for a Healthy Environment, Southern Utah Wilderness Alliance, Utah Chapter of Sierra Club, Grand Canyon Trust and Great Old Broads for Wilderness (Living Rivers).

As the Director of the Utah Division of Water Quality (Director) recognizes, almost the entirety of the Bruin Point Mine sits within the headwaters of Range Creek, an important tributary to the Green River. While we continue to disagree with the Director over what constitutes the threshold amount of ground water worthy of protection under Utah law, there is no question that under any standard such an amount exists at this site. And, while we understand the desire of Green River Resources, Inc., American Sands Energy Corporations (American Sands) to protect its proprietary solvent from disclosure, it is completely inappropriate for the Director to consider authorizing a Ground Water Discharge Permit (GWDP) without requiring the company to reveal the composition of that solvent. As we outline in detail below, knowledge of the makeup of that solvent is critical to evaluating whether the company's proposed process and guarantees of ground water protection are feasible and defensible. Given the potential consequences to ground water resources, the Director should not be playing hide and seek with the company over the solvent it intends to use. Without this information, there is no basis on which the Director can issue a final GWDP.

Further, the Director has not required American Sands to provide a complete description of ground water resources in the area of the mine. Instead, the Director is content with a single survey, completed in October 2012. This failure to require the requisite information is a violation of the regulations in and of itself. Moreover, without this information it is impossible for the Director to devise an adequate sampling and analysis plan. The Director also focuses almost exclusively on the mine's surface facilities and fails to require the company to provide adequate information related to its underground mine works – including how it intends to

backfill the mine. Because a failure to properly backfill is likely to result in subsidence fractures, this information is critical. Further, because he has not considered the possibility of subsidence fractures, the Director has not taken into consideration the possibility that local surface and ground water resources could be adversely affected by subsidence. He therefore fails to require the company to adequately address the issue or to account for the possibility of subsidence in its monitoring plan.

Regarding the issue of the surface tailings features, the information in the Statement of Basis (SOB) related to the composition and permeability of the base liner and cover differs from what the company provided in its GWDP Application (Application) and must be corrected. Additionally, the Director must require American Sands to provide statistically meaningful testing on representative samples that will be used to construct the tailings features, and should consider alternative cover designs to achieve the expected long-term performance. Finally, while dry tailings does represent Best Available Technology for mine tailings storage, the Director must require the company to perform best management practices in the handling of the storage area.

The Amount of Residual Solvent Permitted in the Tailings Does Not Account for the Bitumen-Equilibrated Solvent.

In both the Statement of Basis (SOB) and the GWDP, the Director refers to the minimal quantity of solvent that may be present in the tailings as 25 mg/kg. SOB at 2, 5, 6; GWDP at 3, 10. However, in violation of Utah Admin. Code R317-6-6.3(F), the information contained in the Application and the GWDP is insufficient. Not only has the company failed to reveal to the Director, and the public, the chemical and toxic characteristics of the leachate to be discharged, but the Director provides no basis for the permit limit he imposes. Further, the permit limit focuses exclusively on the presence of solvent in the tailings alone and does not account for the existence of bitumen-solvent compounds (bitumen-equilibrated solvent). *See* Dr. William Johnson Review at 1, Exhibit A, attached. A permit limit that accounts for bitumen-equilibrated solvent and establishes an appropriate amount of these compounds in the tailings must be included in the permit because dissolution of bitumen compounds into water will be facilitated by the bitumen-solvent compounds. *Id.*

Further, the company's proposed process temperature of 300 °F does not account for the presence of bitumen-equilibrated solvent and is not sufficient to achieve the company's claimed results. *Id.* at 2. While it is possible that the solvent itself will evaporate at 175 °F – although the Director has failed to verify this claim – the proposed 300 °F processing temperature is insufficient to evaporate many of the polycyclic aromatic hydrocarbons within the bitumen that will react with the solvent. *Id.* For instance, the boiling temperature of benzo(a)pyrene is 923 °F, while that of naphthalene is 424 °F. Because of the predicted poor solvent recovery at 300 °F, the Director must require the company to fully substantiate its claims that it will be able to meet the 25 mg/kg permit limit. *Id.* at 2-3. It is not enough for the Director to hope that American Sands' claims will be substantiated once it is up and operating. Beyond being a

violation of R317-6-6.3(F), this simply too little, too late. By the time the company reaches the point in the mining process where it will be producing tailings from its facilities, significant ground disturbance and threats to the watershed would already have occurred. The time for the Director to obtain this information is now, before mining operations are underway, by requiring the American Sands to disclose the chemical makeup of the solvent mixture and to conduct bench-top tests to demonstrate that the company's process is able to perform as it claims. *Id.*

The Absence of Stated Amounts of the Constituents of the Solvent Make it Impossible for the Director to Assess the Toxicity of the Solvent and its Dissolution Into Water.

Without knowing the specifics of each of the solvent constituents, or the composition of the bitumen-equilibrated compounds, information required by R317-6-6.3(F), it is impossible for the Director to ascertain whether the content of the Dense Nonaqueous Phase Liquids (DNAPL) cited in the Wilson study is representative of the bitumen-equilibrated compounds that will be left in the tailings. Johnson at 2. In order to overcome this shortfall, the Director must require American Sands to produce analysis that shows whether the two DNAPLs are comparable through measurement of the air-water interfacial tension of the bitumen-equilibrated solvent, as well as the wetting properties of the residual on the tailings grain surfaces. *Id.*

Additionally, a major shortcoming of American Sands' citation of the Wilson study is that the porosity of the Wilson medium was 0.33, which is indicative of well-sorted sand. *Id.* The American Sands' tailings, however, will be poorly sorted and will likely have porosity lower than the Wilson medium. *Id.* Also, while the residual DNAPL content is highly dependent on the media grain size and moisture content, neither of those factors were considered in adopting the Wilson values. *Id.* Based on Dr. Johnson's analysis of the retention capacity of the tailings, he estimates that the value of residual bitumen-equilibrated solvent that would adhere as DNAPL to the tailings surfaces to be 2500 mg/kg, which is 100 times greater than the permit limit of 25 mg/kg. *Id.* at 2-3. As stated above, given the poor recovery of solvent at 300 °F, a 100 times reduction in solvent recovery during heating is unrealistic, and the Director has no basis for approving such a limit. *Id.* at 3.

Without knowing the exact amounts of the constituents in the solvent, the Director cannot adequately determine the threat this project poses to ground water. Several of the solvent compounds are highly soluble in water, such as alcohol, benzoic acid and methyl tert butyl ether (which is a significant ground water contaminant). *Id.* Additionally, some of the constituents, such as hexane(s), are highly toxic. As Dr. Johnson has established in relevant circumstances, the toxicity of the tailings is increased because the solvent-bitumen mixture includes highly carcinogenic compounds. *Id.*

The Director Must Require American Sands to Clarify Whether the Stated 10% Moisture Content of the Tailings is on a Per Volume or Per Mass Basis

The question of whether the 10% percentage of moisture content in the residual tailings is appropriate depends on whether that moisture content is expressed on a per volume or per mass basis. SOB at 3. Because this relates directly to the question of mobility and the possibility of the residual solvent-bitumen compounds in the tailings to contaminate ground water, the Director must require American Sands to clarify the stated moisture content. *Id.*

The Director Must Require American Sands to Provide Accurate Information Related to the Backfilling of the Mine.

In violation of R317-6-6.3(J), the Director has not required American Sands to provide detailed information on how the company plans to backfill the mine with 29 million cubic yards of tailings. Information on how the mine will be backfilled is necessary for the Director to determine how likely it is that there will be subsidence in the mine sufficient to cause subsidence fractures that would threaten ground water quantity and quality of the aquifer that exists above the mined area. *See* discussion of subsidence below. In the draft GWDP, the Director has not adequately accounted for possible impacts to ground water from the 400 acres of underground mine workings and has not met his legal obligations to do so.

Further, it is unrealistic for the company to claim that it will backfill approximately 60% of its tailings into the mine. *See* Kuipers Expert Report (Kuipers) at 4, Exhibit B, attached. Because mining experience shows that a maximum of approximately 55% backfilling of tailings is achievable, the Director must require American Sands to revise its application to reflect this reality. *Id.* This is critical in order to ensure that adequate surface tailings facilities are available – something that currently isn't accounted for in the GWDP and Construction Permit. *Id.*

The Director Must Require American Sands to Provide Accurate and Complete Information Related to Ground Water in the Affected Area.

In violation of R317-6-6.3(D), (E) and (K), the Director has not required American Sands to provide a complete and accurate description of ground water in the affected area of the mine. *See* Elliott Lips Expert Report (Lips), Exhibit C, attached. Because of this failure, the Director cannot identify possible impacts to ground water in the area of the mine and cannot develop a meaningful sampling and monitoring plan. Lips at 4. The Director not require the company to conduct multiple field surveys in order to obtain a complete and accurate understanding of the seasonal occurrence of seeps and springs near the mine. *Id.* In the one seep and spring survey conducted in October, 2012, American Sands noted three potential seeps and two potential springs, all five of which contained wetland grasses, indicating saturated conditions at certain times of the year. *Id.*; *see also*, GWDP Application, Appendix F at 11. However, because the Director did not require American Sands to conduct seasonal surveys of seeps and springs, the Application contains an incomplete and inaccurate description of ground water that could be

impacted by the mine. Lips at 4. Specifically, the Director must require the company to provide information related to the seasonal variability in ground water flow, the seasonal flow at the five potential seeps and springs, and any seeps and springs that were not flowing at the time of the initial survey. *Id.* This information is necessary in order to devise an appropriate sampling and analysis monitoring plan as required by R317-6-6.3(I).

Additionally, because the Director has not adequately considered the possible impacts to ground water based on the underground mining operations, the Director has not required American Sands to conduct additional investigations so that it can more fully understand the extent of the aquifer between the surface processing facility and the underground mine. *Id.* Specifically, the Director must require the company to provide information detailing the saturated thickness, flow direction, hydrologic conductivity and flow system characteristics of that aquifer(s) as required by R317-6-6.3(K). *Id.*

The Director Must Require American Sands to Provide a Complete Sampling and Monitoring Plan.

Because the Director has not required American Sands to provide a complete and accurate seep and spring survey, the sampling and analysis plan approved by the Director is necessarily incomplete in violation of R317-6-6.3(I). The Director must require American Sands to produce a sampling and analysis monitoring plan based on the results of that complete and accurate seep and spring survey. Lips at 6. Further, as noted in detail above, by not requiring the company to provide information related to the chemical composition of the solvent it intends to use, the Director has failed to determine the chemical and toxic characteristics of leachate associated with this mine, in violation of R317-6-6.3(F). This lack of information also makes it impossible for the Director to ensure that the company is meeting the compliance sampling requirements of R317-6-6.3(L). The Director must compel the company to disclose the composition of its solvent. Without that information, the Director has no legal basis for issuing a final GWDP and Construction permit.

The Director Must Require American Sands to Evaluate Subsidence-Related Impacts to Ground Water.

Because the Director has failed to evaluate the possibility that subsidence fractures could have significant and permanent impacts to the ground water quantity and quality, he cannot show that the facility will not impair present and future beneficial uses of ground water in the area of the mine and therefore has violated R317-6-6.4(A)(4). While American Sands claims that no subsidence is expected and that no ground water inflows into the mine are expected, the Director has not required the company to provide any analysis or documentation to support this claim. *See* NOI at 11, Exhibit D, attached. However, subsidence is an inevitable consequence of underground mining and such subsidence causes impacts to, *inter alia*, underground aquifers. Kuipers at 2-3. Further, subsidence fractures from underground mines are well documented and have the potential to divert surface and ground water flows into the mine workings. Lips at 5.

In his report, Lips points to impacts from nearby mine works as examples of the type of ground water impact that is likely to occur at the Bruin Point Mine. *Id.* These impacts include: 1) diminished discharge at springs near the mined area; 2) rapid decline in the water levels of the overlying aquifer when the aquifer was fractured; 3) draining of an aquifer into mine cavities along conduits created by subsidence fractures; 4) diversions of surface water into the subsurface through fractures; 5) rapid degradation of ground water quality through diversions; and 6) increased TDS concentrations in surface water down valley from the mine. *Id.*; *see also* Dunrud, Lips Attachment D; Slaughter, Lips Attachment C.

Should subsidence fractures occur, they will almost certainly intercept the overlying shallow aquifer at the mine site and the flow of water along the fractures will result in a rapid dewatering of this aquifer with a subsequent reduction or elimination of the discharge at seeps and springs. Lips at 5-6. Such an occurrence will also result in degradation of ground water quality as water passes through different rock types – resulting in either degraded surface water quality in Range Creek, or saturation of the tailings in the underground mine. *Id.* Kuipers agrees that both short-term and long-term adverse impacts to aquifers would likely result from this mine and that once mining begins, it is very difficult to mitigate the effects on the environment caused by subsidence. Kuipers at 3. To help moderate this inevitability, Kuipers suggests that a 45 degree maximum impact area be utilized instead of the company's suggested 20 degree angle of draw for impact from underground mining. *Id.*

Because the Director has not considered possible impacts from subsidence fractures, he has not required the company to conduct surface or ground water monitoring that could detect the occurrence of such fractures. Lips at 6. As subsidence fractures will almost certainly intercept the shallow aquifer above the mine works, a monitoring plan that considers such a possibility and that detects changes in ground water quantity or quality is necessary. *Id.* at 6-7. Lastly, because of the possibility of subsidence fractures, monitoring surface water at only one location in Range Creek is insufficient. *Id.* at 7. The Director must account for subsidence fractures, and must require American Sands to monitor for changes in surface flows in multiple locations. *Id.*

In its NOI, American Sands insists that it will achieve “total support” for the mine using the room and pillar method. NOI at 11. However, such a contention is unsupportable because the concept of “total support” has not been achieved in underground mining using room and pillar methods. Kuipers at 3. Given that this assertion serves as basis for the company's further statements regarding subsidence, the Director must require American Sands to provide scientific proof of its claim that its design of its underground mine will provide “total support” for the mine. *Id.* Without such proof, the Director has no basis for accepting the company's declaration of performance.

Because of the likelihood of subsidence and subsequent negative impacts on aquifers that exist above the mine, the Director must require American Sands to identify and develop

subsidence and hydrologic impact plans and incorporate the results of these plans into its Application before final approval is given. *Id.* Additionally, because a diversion of the aquifer(s) that exist above the mine would put significant quantities of pristine ground water in direct contact with tailings containing residual bitumen-equilibrated solvent, thus creating an unanticipated discharge from the mine, the Director must comply with his obligations under R317-6-6.3(G) and require the company to demonstrate that such a discharge can be controlled. Given the overwhelming documentation of subsidence-related impacts to both surface and ground water quantity and quality in similar geologic settings, the Director's determination that permanent disposal of tailings in the mine works would have a *de minimis* effect on ground water quality is without basis.

The Director Must Clarify the Composition of the Tailings Base Liner and Cover, Must Require the Company to Supply Statistically Meaningful Tests of Materials to be Used in the Tailings Features, and Must Require American Sands to Conduct Best Management Practices for the Tailing Storage.

The Application notes that the compacted base liner for the tailings area will consist of four feet of sorted material with a permeability of 2.3×10^{-7} . Application at 5. Regarding the cover for the tailings area, the Application states that it will consist of four feet of removed and stored growth media with a comparable permeability. *Id.* However, the SOB states that both the base liner and the cover will each be made of a clay liner with a permeability of 1×10^{-7} . The information in the Application and/or the SOB must be revised to be consistent and accurate.

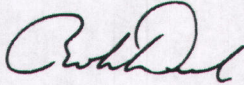
Further, the company only provided the Director with permeability information from one sample, which the Director then used to base his decision on. Kuipers at 4. This is statistically irrelevant and the Director must require the company to conduct additional tests on representative samples that will be used to construct the tailings features. *Id.* Additionally, because of long-term issues associated with clay liners, the Director must require American Sands to address how it intends to ensure that the clay liner performance will be ensured. *Id.* Kuipers suggests that the Director consider alternative cover designs to achieve the expected performance over the long-term. *Id.*

Finally, while dry tailings does represent the Best Available Technology for mine tailings storage, the Director must require the company to undertake certain measures in order to ensure that the tailings storage area performs according to expectations. First, the dry tailings should be compacted in 2 foot lifts as they are place to provide for consolidation prior to cover placement. *Id.* Second, seasonal storm precipitation must be accounted for and provisions made to either cover the tailings or allow for drying following precipitation events. *Id.* Third, the tailings should be concurrently covered and reclaimed at the earliest possible opportunity in order to maintain their dry condition and reduce potential for seepage. *Id.*

Conclusion

Thank you for the opportunity to comment on this Draft Permit. As always, we very much appreciate your willingness to consider our input and to work with us towards improving Utah's ground water quality.

Yours,



Rob Dubuc

Joro Walker

Attorneys for Living Rivers

Exhibit List

Exhibit A – Johnson Review

Exhibit B – Kuipers Expert Report

Exhibit C – Lips Expert Report

Exhibit D – American Sands Notice of Intention to Commence Large Mining Operations

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May 26, 2015

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RE: Expert Report – Utah Ground Water Discharge Permit Application for Green River Resources (GRR) American Sands Energy Corp Bruin Point Mine, April 2015

Dear Mr. Dubuc:

This letter constitutes my expert report in connection with GRR's proposal to mine and process tar sands before the Utah Division of Water Quality (DWQ).

1.0 INTRODUCTION

1.1 Background

I am a Professional Geologist licensed in the States of Utah and Wyoming. In 1983, I received my Bachelor's degree from Western State College of Colorado with a double major in geology and physics. In 1990, I received my Master's Degree in geology from Colorado State University. Between 1983 and 1985, I was employed by the U.S. Geological Survey. During this time I participated in, researched, and co-authored several studies relating to ground water movement and landslides, as well as surface water flooding. Most of the investigations were on sites of recent flooding and landslide activity in central Utah.

Between 1985 and 1997, I was employed as a full-time consulting engineering geologist. During this time I conducted approximately 15 investigations for ground water contamination from mines, mills, smelters, tailings ponds, and other industrial facilities in Utah, Colorado, Nevada, and California. I participated in four separate seep and spring surveys for existing and proposed mines in Utah and Nevada, ranging in size between 2 and 50 square miles. I have supervised the installation of approximately 100 ground water monitoring wells using a variety of drilling methods and in a variety of geologic materials. I performed hydrology and hydraulics analyses and designed runoff control plans at numerous mine and industrial facilities in Utah and Nevada. I prepared geology, hydrology, and engineering components of mining and reclamation plans and ground water discharge permits for 21 open-pit and underground mines, mill and concentrator sites, smelters, and tailings impoundments.

Between 1996 and 2006 I was an Adjunct Associate Professor in the Department of Geography at the University of Utah. I taught classes in geomorphology (including surface and ground



water systems), environmental studies, climate change, and resource conservation and environmental management.

In the past 30 years, I have assisted in the preparation of geology, hydrology, and engineering portions of mining and reclamation plans at six coal mine facilities in Utah (Knight Mine, Star Point Mine, Soldier Canyon Mine, Sunnyside Mines, Horse Canyon Mine, and the Rilda Canyon Mine). I have also supported permitting activities at five non-coal mine facilities in Utah (Mercur Mine, Kennecott [mine, mill, smelter, and tailings pond], Carr Fork Mine, IS&R [mill site and tailings pond], and the Goldstrike Mine). In addition to permitting activities for the Division of Oil Gas and Mining, I have prepared permit applications for ground- and surface-water discharge.

In the past 17 years, I have provided permitting expertise in the areas of geology and surface and ground water quality and quantity for proposed mines, tailings ponds, dams, highways, coal ash landfills, and river diversions. These projects have involved review of Ground Water Discharge Permits, Coal Ash Landfill Permits, NEPA documents, 404 Permit Applications under the Clean Water Act, UPDES Permits, Federal Energy Regulatory Commission (FERC) Applications, and Utah Division of Oil, Gas and Mining and Reclamation Plans.

During my professional career, I have provided consulting services to federal, state, and local governmental agencies, private industry, and non-governmental organizations. I have prepared reports and provided expert testimony twice in Federal Court, at several hearings before the Utah Board of Oil Gas and Mining, and before an Administrative Law Judge in Division of Water Quality proceedings.

My Curriculum Vitae is found at Attachment A.

1.2 Facts and Data Considered

To prepare this report, I reviewed the following documents: 1) Utah Ground Water Discharge Permit Application (Application) submitted by GRR to the Utah Division of Water Quality (DWQ), dated April 2015; Notice of Intention to Commence Large Mining Operations (NOI) submitted to Utah Division of Oil, Gas and Mining, dated March 2015; and 3) Statement of Basis Ground water Discharge Permit No. UGW070003, Draft Public Notice Version dated April 28, 2015 (SOB).

1.3 Geology of Proposed Mine Site

The Parachute Creek Member and Garden Gulch Member of the Green River Formation are the surface bedrock formations that outcrop at the project area and in several small canyons across the site. The Colton Formation is exposed at the surface in the southwest portion of the lease area (Application, pgs. 17-18 and Figure 3). The oil sands to be mined occur in the upper part of the Colton Formation and lower part of the Green River formation (Garden Gulch and Douglas Creek Members).



2.0 INACCURATE DESCRIPTION OF THE AFFECTED AREA

GRR proposes to conduct underground mining and bitumen and hydrocarbon extraction within the 1,760-acre lease area. The total area of the land affected by these activities is 560 acres; 160 acres of surface land disturbance and 400 acres of underground mine workings (NOI; p. 22, Figure 14). DOGM was very clear in explaining to GRR that “Disturbed Area” means surface land disturbed by mining operations, and that “Land Affected” means the surface and subsurface of an area within the state where mining operations are being or will be conducted (NOI response to Comments #2 and #29).

However, in the Application, GRR refers to the “Affected Area” as 160 acres (pg. 2 and Figure 2). The 160 acres that GRR implies is the “Affected Area” is in fact only a small portion of the total acreage that will be affected by the mining and extraction operations. GRR, inaccurately, implies that the 160 acres of the surface disturbance is the only portion of the lease area that will be affected.

This is not a matter of semantics. The delineation of the Affected Area permeates throughout the Application and affects the description of the ground water in the vicinity of the project area, the potential impacts to ground water, and the monitoring plan.

The Application makes cursory mention to placing tailings in the underground workings after the fifth year of operations (Application, p. 7). However, DWQ has not required GRR to provide any information on the quantities, the location within the mined areas, or information on how the tailings will be placed. GRR states that there will be no anticipated impact to surface or ground water resources, but provides no supporting data or analysis. This is not a trivial issue because GRR proposes to permanently dispose of 29 million cubic yards of tailings containing residual solvents and hydrocarbons in the underground mined areas (NOI; p. 21). DWQ has not required GRR to provide information to support DWQ’s position that the disposal of these tailings would have a *de minimis* effect on ground water quality (See SOB; pg.4).

3.0 INCOMPLETE DESCRIPTION OF GROUND WATER IN THE AFFECTED AREA

The Application documents the presence of ground water in a shallow (<100 feet below ground surface) aquifer as evidenced by discharge from springs and seeps in the headwaters of Range Creek (Application, p. 2). Ground water in this aquifer flows down-dip towards Range Creek, where it discharges from North Spring and other smaller seeps and springs within the Range Creek channel (Application, Appendix B, pg. 3). Ground water in this aquifer appears to be contained in near-surface stress-relief fractures (Application, Appendix B, pg. 5).

The shallow aquifer is a significant source of recharge to Range Creek. Discharge from North Spring alone has been measured at approximately 40 gallons per minute (gpm). In addition two wells drilled by Amoco topographically up dip from North Spring and within the recharge area of the shallow ground water system documented artesian flow at 50 and 300 gpm (Application, Appendix B, p. 4).



Based on the limited sampling conducted to date by GRR, the shallow aquifer feeding the seeps, springs, and Range Creek is classified as Class IA – Pristine Ground Water according to the Ground Water Quality Protection Rules (R317-6-3.2).

In spite of the presence of a laterally extensive aquifer, with high flow rates of Class IA pristine ground water in the headwaters of Range Creek, the information in the Application fails to provide complete and accurate descriptions required by the Ground Water Quality Protection Rules (R317-6-6.3 (E)(K)). Without this information, DWQ cannot demonstrate that there will not be impacts to the shallow ground water, or that GRR has developed a meaningful sampling and monitoring program.

GRR conducted only a single field survey in October 2012 to identify seeps and springs in the project area (Application, Appendix F, pg. 8). Standard practice in the field of hydrogeologic investigations is to conduct a series of several field surveys during different seasons. This is necessary in order to obtain a complete and accurate understanding of the seasonal occurrence of seeps and springs. One field survey, conducted in the fall, provides extremely limited information and restricts the ability to understand the hydrogeologic flow systems. This is particularly concerning because it was noted that all data collected in 2012 represented the flow and water quality characteristics after a lower-than-normal winter snow pack (Application, Appendix F, pg. 8).

DWQ is aware that subsequent seep and spring inventories conducted in the spring can confirm the presence of ground water resources not identified in the fall. For example, at Red Leaf Resources site, a second field survey conducted in the spring confirmed that several of the seeps identified in the previous fall had significant flow.

The result of the inadequate seep and spring inventory is to under identify and underestimate the number of seeps and springs in the affected and adjacent area. During the October 2012 inventory, JBR noted three “potential seeps” and two “potential springs”; all five contained wetland grasses that indicated saturated conditions during the growing season and some contained evidence of cattle and big game use (Application, Appendix F, pg.11). However, because inadequate surveys were conducted in other seasons, the Application contains no information on the quantity or quality of these resources, and thus the Application does not present a complete and accurate description of the ground water resources that could be impacted by the mining and extraction processes.

Furthermore, the boundary for the October 2012 inventory does not cover all of the Affected Area. A comparison of Figure 1 in Appendix F of the Application with Figure 14 of the NOI reveals that there is a significant portion of the Affected Area that was not included in the inventory.

Given the importance of the seeps and springs within and near the Affected Area, and their potential of being impacted by the mining activities, it is imperative that additional investigations be conducted to more fully understand the aquifers in which the ground water occurs, the saturated thickness, flow direction, porosity, hydrologic conductivity, and flow system characteristics as required by R317-6-6.3 (K). As part of these investigations, it is essential that GRR conduct additional seep and spring inventories, especially during the spring months, in order to: 1) understand seasonal variability in ground water flow, 2) assess flow at the five



“potential seeps and springs” identified in the October, 2012 inventory, and 3) identify additional seeps and springs that were not flowing at the time of the initial survey. Only when these data are collected and analyzed will it be possible to assess potential impacts from the mining operations and develop a meaningful sampling and monitoring plan. DWQ has not required GRR to collect and analyze these data.

4.0 FAILURE TO EVALUATE SUBSIDENCE RELATED IMPACTS TO GROUND WATER

GRR proposes to remove approximately 54 million tons of ore from approximately 400 acres of underground room and pillar mining operations (NOI; p. 13, p. 22). The mine height varies depending on the thickness of the ore seam, which averages approximately 60-70 feet and can be as thick as 100 feet (NOI, p. 13). GRR proposes to permanently dispose of 29 million cubic yards of crushed sand tailings containing residual solvents and unprocessed hydrocarbons in the underground mined areas. Approximately 60 percent of the mine workings will be filled by the sand tailings and sorted waste (NOI; p. 21). According to GRR, the tailings will contain as much as 25 ppm of solvent (w/w) (NOI; p. 18).

GRR claims that no subsidence is expected and that no ground water inflows are expected (NOI; pg. 11). However, DWQ has not required GRR to provide any analysis or documentation to support this claim. Furthermore, this claim is completely at odds with a copious body of research on subsidence related impacts to ground water (See: Blodgett and Kuipers, 2002 and references therein (Attachment B); Slaughter, et. al., 1995 (Attachment C); Dunrud, 1976 (Attachment D); and Lee and Abel, 1983 (Attachment E)).

Subsidence fractures can have significant and permanent impacts on the ground water quantity and quality in the shallow aquifer overlying the proposed Bruin Point mine area. This aquifer, containing Class 1A pristine ground water is currently a significant source of discharge into the headwaters of Range Creek.

Impacts to overlying ground water and surface water resources from subsidence fractures that propagate from mines to (or near) the surface are well documented. For example, at a mine in similar stratigraphy and in close proximity to the proposed Bruin Point Mine, Dunrud (1976, pg. 9) noted that subsidence fractures “... divert all surface- and ground-water flow in this area to lower strata or to the mine workings.” Slaughter, and others (1995) investigated subsidence related impacts on hydrologic resources. They document: 1) diminished discharge at springs near the mined area, 2) rapid decline in the water level of the overlying aquifer when the aquifer was fractured, 3) draining of an aquifer into mine cavities along open conduits created by subsidence fractures, 4) diversions of surface water into the subsurface through fractures, 5) rapid degradation (increased TDS) of ground-water quality related to faster than normal ground-water flow between strata of different lithologic character enhanced by the formation of open vertical fractures, and 6) increased TDS concentrations in surface water down valley from the mine.

At the proposed Bruin Point mine, subsidence fractures will almost certainly intercept the overlying shallow aquifer. Flow of water along fractures would result in a rapid dewatering of this aquifer with a subsequent reduction or elimination of discharge at seeps and springs. The water quality of the ground water would likely degrade as the water flow passes through



different rock types. This degraded water could either discharge further down gradient into Range Creek, thereby reducing the surface water quality, or could flow into the mined area and saturate the tailings.

At this time, it is not possible to state with any degree of certainty what the ultimate fate and water quality of this ground water will be. However, it is almost certain that the water quality will further degrade, possibly including some of the solvent remaining in the tailings. Ultimately, this highly contaminated ground water will move down gradient and impact other aquifers and/or discharge to the surface in the Range Creek drainage.

DWQ has not required GRR to provide the results of any analysis of the potential impacts to surface or ground water from subsidence related impacts. Furthermore, given the overwhelming documentation of subsidence related impacts to both surface- and ground-water quantity and quality in similar geologic settings, DWQ's determination that permanent disposal of 29 million cubic yards of tailings in the mine workings would have a *de minimis* effect on ground water quality is without basis (See SOB; p. 4).

5.0 INCOMPLETE SAMPLING AND MONITORING PLAN

GRR proposes to monitor surface water quality and quantity from only two springs, one seep, one location in Range Creek, and the storm water retention basin. The locations of the four surface water sampling locations were determined based on the JBR seep and spring inventory. In addition, GRR proposes to install up to five ground water monitoring wells in the vicinity of the surface tailings disposal area, and three monitoring wells in the vicinity of the process area (Application; Appendix H, pgs. 1-3 and Figure 2-1). According to GRR, "...The goal of the surface water sampling is to monitor for potential impacts to surface water adjacent to the proposed mining and ore processing activities. The goal of the groundwater sampling is to monitor for potential impacts to groundwater downgradient of proposed processing and stockpiling operations" (Application; Appendix H, p. 1).

GRR's sampling and monitoring plan is inadequate for the following reasons.

First, because GRR has not conducted a seep and spring inventory in the spring, the Application does not contain a complete and accurate description of the ground water resources that could be impacted by the mining and extraction processes, and upon which the monitoring plan should be based. As discussed above in Section 3.0, three potential seeps and two potential springs, all five containing wetland grasses that indicated saturated conditions during the growing season and some containing evidence of cattle and big game use were identified in the October 2012 seep and spring inventory. GRR proposes no monitoring of these locations. In fact, GRR only proposes to monitor two springs within the entire Range Creek drainage basin within and near the affected area.

Second, GRR proposes no surface or ground water monitoring intended to detect impacts from subsidence related impacts. In fact, GRR does not even consider the 400 acres of the mine workings underlying the Class 1A pristine ground water shallow aquifer to be in the "Affected Area" (See Section 2.0 above). This glaring omission from the monitoring plan is based on the unsupported statement by GRR that no subsidence is expected. As discussed in Section 4.0



above, subsidence related fractures will almost certainly intercept the shallow aquifer with significant and permanent consequences. It is imperative that the monitoring plan be designed to detect any changes to the quantity or quality of surface and/or ground water. It is simply insufficient to rely on GRR notifying DWQ if "significant" ground water flow is observed as the mine is developed (SOB; p. 4). Although this might require modifying plans for the disposal of the underground tailings (if possible), it does nothing to address impacts to the overlying aquifer.

Third, GRR plans to monitor surface water at only one location in Range Creek. Given the hydrogeology of the mine area, and the potential for subsidence fractures to intercept ground water from the shallow aquifer that supports flow in Range Creek, one sampling location is insufficient.

DWQ has not required GRR to correct any of these inadequacies in the sampling and monitoring plan.

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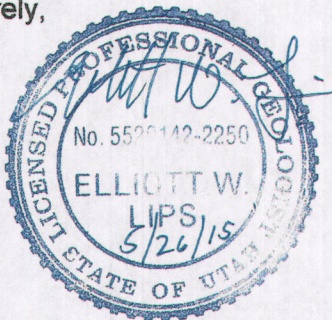
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Sincerely,



Elliott W. Lips, P.G.
Principal Engineering Geologist
Great Basin Earth Science, Inc.

Attachment A – Elliott W. Lips Curriculum Vitae
Attachment B – Blodgett and Kuipers, 2002
Attachment C – Slaughter and others, 1995
Attachment D – Dunrud, 1976
Attachment E – Lee and Abel, 1983

May 27, 2015

Rob Dubuc
Western Resource Advocates
150 South 600 East, Suite 2A
Salt Lake City, Utah 84102

Re: Bruin Point Tar Sands Project
Comments on Proposed Ground Water Discharge Permit No UGW070003

Dear Mr. Dubuc:

This letter constitutes my review comments in connection with Green River Resources, Inc. (GRR) proposal to mine and process tar sands at their Bruin Point Mine and their proposed Ground Water Discharge Permit and related Construction Permit No UGW070003 being considered by the Utah Department of Environmental Quality (UDEQ). In support of these comments I have reviewed and reference the following documents: Utah Ground Water Discharge Permit Application (Application) submitted by GRR to the Utah Division of Water Quality (UDWQ), dated April 2015; Notice of Intention to Commence Large Mining Operations (NOI) submitted to Utah Division of Oil, Gas and Mining, dated March 2015; and Statement of Basis Ground water Discharge Permit No. UGW070003, Draft Public Notice Version dated April 28, 2015 (SOB).

BACKGROUND

I have a B.S. in Mineral Process Engineering from Montana College of Mineral Science and Technology (1983). I am a Professional Engineer (PE Mining/Minerals) currently registered in the states of Montana and Colorado. I have more than 30 years of professional experience in the mining industry and mining environmental compliance. A full resume is attached.

Since 1996, I have been the principal of Kuipers & Associates, LLC based in Wisdom, Montana. Kuipers & Associates provides engineering consulting and other technical services to a variety of clients including local, state, federal and tribal government and non-government public interest organizations. Kuipers & Associates specializes in mine permitting, operations, reclamation and closure. We have a particular emphasis on mine site characterization, toxic release response planning including the use of source controls as well as wastewater management and treatment, as well as associated cost estimation and financial assurance. I am the principal consulting engineer.

SITE INFORMATION

American Sands Energy Corporation (American Sands/the Company) has acquired rights to tar sands deposits covering approximately 1,760 acres (known as the Sunnyside deposit) in the Bruin Point area in the Book Cliffs of Utah. The Company is proposing to use room and pillar underground mining methods and has licensed proprietary extraction technology for a bitumen and hydrocarbon extraction process that separates oil and other hydrocarbons from shale. American Sands is proposing to produce and deliver approximately 5,000 barrels per day of bitumen extracted from the Green River Formation oil sands. Following crude oil extraction, sand tailings (clean dry sand) will be stored in a surface sand tailings storage area (which will consist of dry material with no tailings pond). As mining activities advance, sorted sand tailings will be used as underground mine backfill.

COMMENTS

Potential for Mine Subsidence and Impacts on Groundwater

According to the SOB (p. 4) “It should be noted that the proposed mine workings will be approximately 500 feet lower in elevation than the tailings disposal area, well below the shallow ground water system, and are located west of it. With present knowledge of subsurface conditions, there is no reason to suspect there would be significant ground water flow into the mine workings, and under these conditions, disposal of tailings into the workings would have a *de minimis* effect on ground water quality.”

According to the NOI (p. 11) GRR does not anticipate subsidence: “The mine plan is for total support based on rock strength properties measured from ore recovered from the T37 zone in 2013. Generally, the entries/rooms will be mined to approximately 50 feet in width with associated pillars at 50 feet by 50 feet. The mining height depends on the T37 seam thickness and has the potential to be as much as 100 feet. Site conditions may require changing the room width and pillar size to make certain that the workplace is safe and supported. No subsidence is expected as the mine design is for total support utilizing a room and pillar mining method. It is expected that the abandoned workings would remain in a totally supported configuration in perpetuity following closure and abandonment (underline added). No inflows of groundwater are expected nor would surface water be allowed to enter the portal entries as they would be closed at the end of mine life.”

I have studied mine subsidence in detail and have authored a report titled *Underground Hard-Rock Mining: Subsidence and Hydrologic Environmental Impacts*.¹ In brief, subsidence is an inevitable consequence of underground mining – it may be small and localized or extend over large areas, it may be immediate or delayed for many years, but it inevitably occurs due to the forces of gravity. Underground mine subsidence in turn causes impacts to hydrologic features like lakes, streams, wetlands, and underground aquifers. Modern mines, using large-scale methods like room-and-pillar mining, create large areas of hydrologic and subsidence related impacts that can extend well beyond the area of measurable ground movement. Most studies of

¹ Underground Hard-Rock Mining: Subsidence and Hydrologic Environmental Impacts, By Steve Blodgett, M.S. and James R. Kuipers, P.E., Center for Science in Public Participation, Bozeman, MT, February 2002

subsidence and hydrology impacts and their associated environmental effects have been done on underground coal mines. However, the fundamental engineering principles of hydrology and subsidence are the same for coal and tar sands mines.

Room and pillar mining can result in short-term impacts to aquifers and overlying features during operations due to mine dewatering and longer-term due to subsidence impacts. The effects on the environment may develop slowly over years in the form of degraded water quality, lowering of the water table, and chronically unstable ground. Methods used to predict subsidence and hydrologic impacts are not reliable when applied to the more complex geologic and hydrologic conditions found at most mines. Mines may contain faults and folds and hydrothermally altered rocks, which complicate and exacerbate subsidence and hydrologic impacts. Once mining begins, it is very difficult to mitigate the effects on the environment. There is little evidence in the scientific literature demonstrating effective mitigation of subsidence or hydrologic impacts at underground mines. Consequently, the environmental impacts from mining may worsen over time as the ground continues to settle and aquifers are de-watered or degraded.

Recommendation: Under the federal Surface Mining Control and Reclamation Act of 1977 (SMCRA) a coal mine is required to identify and develop subsidence and hydrologic impact plans before mining begins to deal with potentially negative environmental impacts. The UDWQ should require GRR to identify and develop detailed subsidence and hydrologic impact plans and incorporate the results of those plans into the Application before it is further considered.

It should be noted that the NOI (p. 12) contradicts itself by suggesting that despite “total support” GRR proposes to maintain a buffer around Range Creek beneath which no underground mining would take place, “... thereby preventing it from being impacted by underground mining.” This statement admits that underground mining can and is otherwise likely to have an impact on overlying hydrology. The NOI further contradicts itself by suggesting that a catastrophic mine collapse could result in subsidence. While we agree that a catastrophic mine collapse could result in subsidence, based on the scientific evidence it is much more likely that subsidence will occur over a longer time-frame (e.g. years, decades or centuries).

Recommendation: The UDWQ should require that the Application be further supported by additional information on the concept of “total support” as there is no scientific evidence for such a concept much less an actual demonstration of its achievement in underground mining using room and pillar methods. While it may be possible to some extent by completely backfilling the mine, that aspect is not guaranteed and could be precluded by early closure or due to discovery of water in the mine workings which would preclude backfilling. The Application is also based on the assumption of a 20 degree (measured from vertical) angle of draw for impact from underground mining – the literature clearly suggests the area of impact, particularly from a hydrologic viewpoint, may be much greater and therefore it is recommended that a 45 degree maximum impact area be utilized instead of 20 degrees.

Mine Backfill

According to the SOB (p. 2) GRR plans to eventually dispose of the residual tar sands tailings by backfilling them in the underground mine workings; however, tailings will initially need to be placed on the surface for disposal, due to the need to create space in the underground mine workings for tailings disposal and also because of the increase in volume when bitumen-impregnated sandstone is crushed before processing. Underground tailings disposal will take place after year 5 of operation and will likely not happen until after this permit is renewed (p. 7). According to the Application (p. 25), approximately 60% of the underground mine workings will be backfilled with the material from the sand tailings storage area, including reserve and reject ore and sand and line tails.

The maximum amount of backfill for any mine is assumed to be approximately 60% by volume due to the difference between in-place rock volumes and broken or ground rock volumes. While many mines utilize backfill experience suggests that the most that any operation has yet to achieve is approximately 55% by volume.

Recommendation: The application should be revised to reflect a more realistic backfill projection and ensure that adequate surface tailings facilities are available.

Tailings Liner and Cover Materials and Specifications

According to the Application (p. 5), “The sand tailings area will be constructed with a compacted base liner approximately four feet thick using sorted material, permeability of 2.3×10^{-7} cm/s consisting of the in-seam partings (underline added) which will reduce the infiltration so low that there is limited infiltration of storm water through the base material, as shown in Appendix G, Preliminary Stability and Hydrology Analyses. As material is placed from the bottom upwards, when final slopes can be reclaimed, a cover consisting of approximately four feet of removed and stored growth media will be used to cover the sand tailings with a permeability of 2.3×10^{-7} cm/s (underline added). The dry tailings liner and cap will be installed to reduce water infiltrating through the dry tailings and impacting groundwater.”

However, according to the SOB (p. 5), “The tailings disposal area will feature a compacted base and cover, each made of 4 feet of clay material with a permeability of 1×10^{-7} cm/sec. The system will include a capillary barrier on top of the clay cover with 18 inches of growth media above the capillary barrier (underline added). A sloped weeping tile will be installed above the clay base and will run downhill from the highest point in the sand pile to a HDPE-lined retention basin.”

The description in the Application suggests the use of “in-seam partings” for the base liner whereas the SOB describes “clay material” for the same purpose. The Application suggests the use of “stored growth media” for the cover whereas the SOB describes a clay cover, a capillary barrier, and 18 inches of growth media. The information as presented is both inconsistent and confusing.

Recommendation: The information in the Application and/or SOB should be revised to be both accurate and consistent.

According to the Application (p. 12), permeability tests were performed on a single partings sample that will be used to construct the liner. Permeability results for this sample were 2.3×10^{-7} cm/s. How does one sample, with a statistical relevance of zero, represent the entire amount of material that might be needed to construct the tailings facility features?

According to Benson et al² there are numerous issues with compacted clay covers intended to result in low hydraulic conductivity. The issues include damage from frost, desiccation, differential settlement and erosion. In general, clay cover performance has not been found to be maintained beyond more than a few years following installation, and is often compromised in the first dry period following a wet year.

Recommendation: The Application and SOB should be revised to address how clay cover performance will be ensured. We suggest the applicant and UDWQ should consider alternative cover designs to achieve the expected performance over the long-term.

Tailings Handling and Concurrent Reclamation

We agree with the SOB (p. 5) that dry tailings is the current Best Available Technology (BAT) for mine tailings storage, particularly from a stability standpoint relative to catastrophic risks, minimization of tailings seepage, and allowing for concurrent reclamation. However, in order to achieve these characteristics a number of aspects which are not addressed in the SOB are required. The first is that the dry tailings should be compacted in approximately 2 ft. lifts as they are placed in order to ensure the tailings are consolidated prior to placement of the reclamation cover. The second is that seasonal storm precipitation should be anticipated which can result in both wetting of the dry tailings and potentially in runoff. Provisions should be provided to either cover the dry tailings or allow for drying following such events, together with storm water controls. Finally, the tailings should be concurrently covered and reclaimed at the earliest possible opportunity in order to maintain their dry condition and to reduce potential for seepage.

Recommendation: The Application and SOB should be revised to address compaction, storm events, and immediate concurrent reclamation of the tailings.

CONCLUSIONS

I have identified a number of potentially significant impacts to ground water due to both the proposed room and pillar mining and tailings storage methods proposed for this project. The present Application and thus SOB does not adequately investigate, describe or provide mitigation for potential underground mining impacts on groundwater, both during operations and that might result long-term from subsidence. The information similarly does not provide

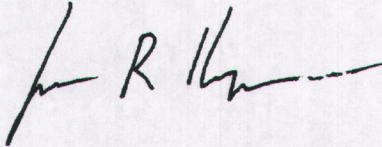
² Benson, C., Albright, W., Fratta, D., Tinjum, J., Kucukkirca, E., Lee, S., Scalia, J., Schlicht, P., Wang, X. 2011. Engineered Covers for Waste Containment: Changes in Engineering Properties & Implications for Long-Term Performance Assessment, NUREG/CR-7028, Office of Research, U.S. Nuclear Regulatory Commission, Washington. <http://www.nrc.gov/reading-rm/doc-collections/nuregs/contract/cr7028/>

Bruin Point Tar Sands Project Comments
May 27, 2015

consistent descriptions of the tailings bottom liner or top cover or ensure that measures are taken necessary to maintain the dry characteristics of the tailings. Based on these shortcomings it is my conclusion that the Application is incomplete and the SOB does not provide information consistent with regulatory requirements.

If you have any questions or require additional information, please do not hesitate to contact me at (406) 689-3464.

Sincerely yours,

A handwritten signature in black ink, appearing to read 'J R Kuipers', followed by a horizontal line.

James R. Kuipers, P.E.
Principal Consulting Engineer
Kuipers & Associates LLC

Attachment: Resume

Review for Western Resource Advocates by

William P. Johnson, Ph.D., Professor

Depts. of Geology & Geophysics and Civil & Environmental Engineering

University of Utah

05-17-2015

Regarding:

STATEMENT OF BASIS

GROUND WATER DISCHARGE PERMIT NO. UGW070003

Green River Resources, Inc. (GRR)

American Sands Energy Corp.

Bruin Point Mine, Carbon County, Utah

April, 2015

Green River Resources (GRR) has provided in its application a list of 12 organic chemicals which includes all constituents of its proprietary solvent. The solvent is immiscible with, and denser than, water (a dense non-aqueous phase liquid – DNAPL). The process will heat the residual sand/solvent/bitumen mixture with the goal being to recover solvent prior to water (for re-use) and then dry the sand prior to disposal. Whereas this is a useful (albeit energy-intensive) step with respect to minimizing residual solvent-bitumen mixture in the disposed sand, the statement of basis (SOB) makes estimates and statements that apply to the solvent alone rather than bitumen-equilibrated solvent. Since the properties of the solvent alone will be very different from the bitumen-equilibrated solvent, there are many issues that need to be resolved as described below.

- 1) The statement of basis (SOB) at the top of page 2 states that no more than 25 mg/kg of DNAPL should adhere to the sand grains. No basis was provided for this statement, either in the SOB or Appendix D, which was referenced for detailed information in the SOB. Furthermore, the calculations in Appendix D consider the solvent only. They do not consider the bitumen-equilibrated solvent. The equilibrated bitumen compounds need also to be included in the limits for disposal since dissolution of bitumen compounds into water will be facilitated by the presence of the solvent compounds (Johnson et al., 2015).

- 2) In the SOB it is stated that the solvent boils at less than 175 °F so it will be evaporated before any water is boiled off from the tailings and the solvent will be reclaimed (page 2, middle). In Appendix D it is specified that the sand will be processed at 300 °F under vacuum (-6 psig). The stated boiling temperatures under this condition are 127 °F for solvent and 186 °F for water. The stated boiling temperature is representative of the solvent alone. It is not representative of the bitumen-equilibrated solvent. The intermolecular interactions will differ in the bitumen-equilibrated solvent residual relative to the solvent. As a result, the boiling temperature of the bitumen-equilibrated solvent mixture will be much higher relative to that of the solvent alone. The boiling temperature of benzo(a)pyrene, representative of the polycyclic aromatic hydrocarbons (PAH) within bitumen, is 923 °F. That of naphthalene, the smallest PAH, is 424 °F. The proposed operating temperature of 300 °F is well below the boiling ranges of bitumen compounds (even under vacuum). It should be expected that solvent recovery by vaporization at 300 °F will be very poor from the bitumen-equilibrated solvent. The stated full recovery of solvent at 300 °F is based on idealized conditions not reflected in the bitumen-residual mixture.
- 3) In Appendix D, residual saturation is defined as the volume of bitumen-equilibrated residual relative to the volume of voids in the tailings ($L^3_{\text{residual}}/L^3_{\text{voids}}$). The authors used a residual saturation value from Wilson et al. (1990) = $0.091 L^3_{\text{residual}}/L^3_{\text{voids}}$. Unfortunately without knowledge of the specific content of each of the solvent constituents, nor knowledge of the content of equilibrated bitumen compounds, it is not possible to know whether the residual content of the DNAPL examined in Wilson et al. (1990) (9.1% v:v) is representative of the actual residual content of bitumen-equilibrated solvent residual in the tailings. The most direct way to understand whether the two DNAPLs are comparable is to measure the air-water interfacial tension of the bitumen-equilibrated solvent, as well as the wetting properties (e.g., via contact angle) of the residual on the tailings grain surfaces. Another major shortcoming of the estimation is that the porosity of Wilson et al. (1990) was 0.33, which is representative of a well-sorted sand; whereas the crushed tailings material will likely be poorly sorted and thereby have lower porosity. As important, the residual DNAPL content is highly dependent on media grain size and moisture content, yet neither media grain size nor moisture were considered in the adoption of the values from Wilson et al. (1990). Based on the poorly justified values used in the estimation, the retention capacity of the tailings (that held by adherence of residual DNAPL) would therefore be: $(0.091 L_{\text{residual}}/L_{\text{voids}}) \times (0.33 L_{\text{voids}}/L_{\text{tailings}}) = 0.03 L_{\text{residual}}/L_{\text{tailings}}$. Since the bulk density of the tailings was measured to be $92 \text{ lb/ft}^3 = 1.5 \text{ kg}_{\text{rock}}/L_{\text{tailings}}$ (in Appendix D): $(0.03 L_{\text{residual}}/L_{\text{tailings}})/(1.5 \text{ kg}_{\text{rock}}/L_{\text{tailings}}) = 0.02 L_{\text{residual}}/\text{kg}_{\text{rock}}$. Assuming the density of the bitumen-equilibrated solvent to be 1.25 kg/L (a mid-range value among solvents): $(0.02 L_{\text{residual}}/\text{kg}_{\text{rock}})(1.25 \text{ Kg}_{\text{residual}}/L_{\text{residual}}) = 0.025 \text{ kg}_{\text{residual}}/\text{Kg}_{\text{rock}}$

= $25 \text{ g}_{\text{residual}}/\text{Kg}_{\text{rock}} = 2500 \text{ mg}_{\text{residual}}/\text{Kg}_{\text{rock}}$. This is the value of residual bitumen-equilibrated solvent that would be adhered as DNAPL to the tailings surfaces assuming that the wetting properties match those of the DNAPL and sediment examined in Wilson et al. (1990). This result is 100 times greater than the $25 \text{ mg}_{\text{residual}}/\text{Kg}_{\text{rock}}$ assumed in the SOB and Appendix D. Given the expected poor recovery of solvent during heating at 300°F (described above), the assumed 100x reduction during heating (2500 to 25 mg/kg) is not unrealistic.

- 4) In the SOB it is states that as part of the extraction process, GRR must monitor the water content of the sand tailings to insure the sand will be dry enough to flow, with moisture content of 10% or less (page 3, top). However, it is not clear whether the moisture content is on a volume per volume or mass per mass basis, which lead to very different outcomes with respect to mobility of the residual fluid. The potential enhanced dissolution of bitumen compounds into water in the presence of solvent compounds is a significant concern with respect to contamination emanating from a residual bitumen/solvent/water mixture (e.g., Johnson et al., 2015).

Based on the review above two suggestions follow:

- 1) GRR needs to provide fully substantiated estimates accounting specifically for the constituent compounds in the solvent as well as the bitumen, or otherwise required to perform bench-top tests to demonstrate that the bitumen-equilibrated solvent actually performs as they claim. This would require demonstration of:
 - a. Solvent recovery from bitumen-equilibrated solvent residual by heating at 300°F .
 - b. Reduction of bitumen-equilibrated solvent residual content by a factor of 100 via heating at 300°F (from 2500 mg/kg to 25 mg/kg as assumed in the SOB and Appendix D).
- 2) The absence of stated amounts of the constituents makes it very difficult to assess potential for dissolution into water and toxicity. Some of the solvent compounds are highly soluble; e.g., alcohol, benzoic acid, and methyl tert butyl ether, the latter being an important groundwater contaminant in its own right. Some of the solvent compounds carry significant toxicity (e.g., hexane(s)). As clarified in Johnson et al., (2015), the issue of toxicity is enhanced by the fact that the residual solvent-bitumen mixture includes highly carcinogenic compounds.

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